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Description

The invention relates to a high-pressure gas discharge lamp provided with a translucent tubular ceramic lamp vessel which is sealed in a vacuum-tight manner, which accommodates a pair of electrodes and an ionizable gas filling and which is provided at its ends with current lead-in conductors each of which is connected to a respective electrode and to a respective external current conductor, at least one current lead-in conductor consisting of an electrically conducting sintered body which contains metal particles between ceramic granules. Such a lamp is known from patent US—A—4,155,758.

Ceramic lamp vessels are used in lamp types in which during operation the lamp vessel is given a very high temperature, for example 900°C or higher. As examples are mentioned high-pressure sodium discharge lamps and high-pressure mercury discharge lamps with halide additions. The term "ceramic lamp vessels" is to be understood to mean herein lamp vessels which comprise monocrystalline or polycrystalline material, such as, for example, translucent gas-tight aluminium oxide, magnesium aluminate, yttrium oxide, yttrium aluminium garnet and sapphire. The polycrystalline material may contain one or more additions which influence the sintering process by which the lamp vessel is formed, for example in the case of aluminium oxide:magnesium oxide and/or yttrium oxide in a quantity of a few hundredths of a per cent.

Both the constituents of the ionizable gas filling of a high-pressure discharge lamp and the coefficient of thermal expansion of the material of the lamp vessel impose stringent limitations on metals which can be used to constitute, in the form of tubes, wires or hoods current lead-in members in the lamp. In lamps destined to be operated with the electrode pair in a vertical position, one of the current lead-in conductors, for example the upper conductor, is sometimes subjected to a more aggressive medium than the other conductor. As a result, in these lamps the choice of material for the one current lead-in member is more strongly limited than for the other conductor. The metal which is used most frequently for a current lead-in member, *i.e.* niobium, has the disadvantage that it is very expensive.

In the lamp according to the said US Patent Specification, a so-called cermet is used as current lead-in member. The ceramic granules of the cermet may consist of the same or of a similar material as the lamp vessel. The metal with its deviating coefficient of thermal expansion is present, dispersed between these granules, in a given volume fraction. With conducting cermets according to this Patent Specification, as the dimensions of the ceramic granules are larger, the volume fraction of metal can be smaller. Nevertheless, at least 4.5% by volume of metal has to be present to obtain a conducting cermet even with the use of large granules (400—800 µm). In the said Specification it is therefore pointed out that fine ceramic particles have to be avoided in order to utilize the metal powder to the optimum.

According to the aforementioned Patent Specification the ceramic granules are coated with a uniform layer of metal powder. In the cermet, the coating layers together constitute a separate continuous phase which has the form of a three-dimensional network of metal and in which the ceramic granules are dispersed as a discontinuous phase. If the ceramic granules are small or if fine particles are present between the ceramic granules, the same volume of ceramic material requires a larger quantity of metal powder to provide the ceramic grains with a uniform coating of metal powder.

Even with the use of large granules (400—800 µm), the conductivity of the cermet according to the said US Patent Specification is still very small. For a cermet comprising these large granules and 4.5% by volume of tungsten powder, a resistivity of 6 Ohm.cm is stated. Such a cermet used as current lead-in conductor leads to high power losses. An additional disadvantage is that large granules cannot be used when the current lead-in member has at least one dimension which is not much larger than the diameter of the granules. If the current lead-in member has one or more small dimensions, small granules and hence a larger volume fraction of metal has to be used.

Especially if the thermal coefficient of thermal expansion of the metal deviates strongly from that of the ceramic material, a large volume fraction of metal is disadvantageous, however. Stresses can then impair the vacuum-tight seal of the lamp vessel.

The invention has for its object to provide a lamp of the kind described in the opening paragraph, in which the sinter body of the current lead-in conductor(s) has a high conductivity, even with the use of comparatively small granules and a small volume fraction of metal particles, and a great strength.

According to the invention, in a high-pressure gas discharge lamp of the kind described in the opening paragraph this object is achieved in that the sinter body of the current lead-in conductor contains ceramic granules, which are embedded in an electrically conducting mass of interweaving networks of ceramic material and metal respectively and in that the volume fraction of the metal particles in the electrically conducting mass, calculated at the theoretical densities of its pure constituents, lies between 15 and 60%.

In the lamp according to the invention, current is supplied to the electrode by a network of metal tracks which is interwoven with a network of ceramic material. These interlocking networks together constitute the continuous conducting phase of the sinter body. This phase is therefore inhomogeneous, which is in contrast with the continuous phase of the sinter body according to the abovementioned US Patent Specification, in which this phase consists entirely of metal. Due to the fact that the mass of the continuous phase consists of metal only for a volume fraction, this mass has in thermal respects to a very considerable extent the properties of ceramic material, but it behaves in electrical respects like a metal. In this conducting mass there are formed cavities which are filled with ceramic granules. As a result, the volume

fraction of metal in the sinter body is small and much smaller than that of the conducting mass. The sinter body consequently behaves in thermal respects (thermal conductivity and coefficient of thermal expansion) substantially like ceramic material, while it has in electrical respects the properties of metal.

It is essential that the continuous conducting phase in the current lead-in conductors of the lamp according to the invention does not consist entirely nor substantially entirely of metal, but only for a given volume fraction. This fraction generally lies between 15 and 60%, mostly between 20 and 50%. With lower volume fractions of metal in the continuous phase, the conductivity of this phase is lost; with higher volume fractions the strength of the sinter bodies strongly decreases and their vacuum-tightness is impaired.

In view of the fact that this conducting phase can be up to five to six times as voluminous as the quantity of metal incorporated therein, in this conducting phase, whilst maintaining a high conductivity, a larger volume of ceramic granules can be incorporated than when the conducting phase consists of the same quantity of unmixed metal, as is the case according to the said US Patent Specification. As a result, the sinter body in the lamp according to the invention can contain a very small volume fraction of metal but nevertheless can have a very high conductivity.

In very favourable embodiments, the volume fraction of the metal in the continuous conducting phase is 30 ± 5%. In these embodiments on the one hand the volume fraction of metal in the continuous conducting phase is so low that the volume of this phase is about three to four times larger than the volume of the quantity of metal incorporated therein, and as a result a large volume of granules can be incorporated therein. On the other hand, in these embodiments the volume fraction of metal in the continuous conducting phase is still so large that the sinter bodies obtained have a very low resistivity combined with a very low volume fraction of metal in these bodies.

The term "volume fraction" with respect to the sinter body of the lamp according to the invention is to be understood to mean: the ratio of the volume of a constituent, for example the metal, to the sum of the volumes of constituents, calculated at the theoretical densities of the pure constituents.

In general, granules having dimensions between 50 to 500 µm are used. The size of the granules in the lead-in conductor may cover this whole range or a sub-range therein, for example, the sub-range from 100 to 400 µm or the sub-range from 400 to 500 µm, or may have a very small spread and be, for example 200 ± 20 µm. The lower limit of the granule size is determined by practical possibilities to remove smaller granules during their manufacture and the upper limit is determined by the dimensions of current lead-in conductors.

The smallest dimension of such a conductor should be a few times, for example five times, larger than the dimension of the largest granule after sintering. The volume fraction of granules in the sinter body may be very high and may amount to more than 95%.

The dimensions referred to are the dimensions of the granules used in the manufacture of sinter bodies. During sintering, about 40% of linear shrinkage occurs, as a result of which granules used have a size of, for example, 400—500 µm in diameter ultimately have a size of about 240 to about 300 µm.

The granules are coarse with respect to the metal powder from which the conducting network in the continuous phase of the sinter body is formed and are coarse with respect to the ceramic powder from which the ceramic network in the continuous phase of the sinter body is formed. In general, metal powder is used therein, whose particles have a size lying between 0.1 and 10 µm. In general, a powder is used having an average particle size lying between 0.4 and 1 µm. Metals which are particularly suitable to be used are W, Mo, Fe, Ta and Nb, as well as combinations thereof. For the ceramic network in the conducting phase use is advantageously made of powder having a specific surface area of about 6—30 m^2/g and a particle size of mainly about 0.3 µm.

The sinter bodies of the current lead-in conductors may have a very low resistivity, which is measured in milliohm.cm, even with a very low volume fraction of metal of, for example, less than 1% by volume.

A directive for the smallest quantity of metal in sinter bodies required for electrical conductivity can be derived from Table 1. This Table shows the relation between this smallest quantity of metal, the volume fraction of metal in the continuous phase and the average size of the granules when metal powder having a particle size of about 0.4 µm and a ceramic powder having a particle size of about 0.3 µm and a specific surface area of 30 m^2/g are used.

TABLE 1

volume fraction metal powder in continuous phase (%)	product of granule size (/um) and minimum volume fraction metal in sinter body (%)
20	590
30	300
50	400
60	420

In this Table "granule size" is the size of the granules before sintering, that is to say before about 40% of linear shrinkage due to sintering has occurred.

It can be seen from Table 1 that the lowest product is found in the righthand column when the quantity of metal powder in the continuous phase of 30% by volume. Consequently, for a given granule size the smallest volume fraction of metal in the sinter body may be used in this case. Therefore with a volume fraction of metal powder in the continuous phase of 30% by volume the minimum required volume fraction of metal is:

with granules of 100 µm, 3% by volume;

with granules of 500 µm, 0.6% by volume.

The sinter bodies generally contain more than the minimum required quantity of metal. The difference in coefficient of expansion between the sinter body and the lamp vessel will also play an important part in choosing the volume fraction of metal in a sinter body. If the lamp vessel has a coefficient of expansion lying between that of the metal and that of the ceramic material of the sinter body, a large volume fraction of metal may be required to make the difference in coefficient of expansion between sinter body and lamp vessel very small.

The sinter body may be manufactured *inter alia* as follows. Ceramic powder is suspended in water. A substance may then be added, which influences the later sintering step, such as MgO. Instead, a magnesium salt, such as the nitrate, may be added. Expressed as MgO, the addition amounts, for example, to 0.03% by weight.

The suspension is dried and the cake thus obtained is broken. The granulate is sieved to remove large lumps. After having been rolled in a ball-mill without balls, the granules are sieved to isolate the desired sieve fraction. When the granules are heated in air, magnesium salts are converted into the oxide.

Metal powder, or instead thereof metal oxide powder, and ceramic powder are mixed in a predetermined volume ratio. This can be effected in a very suitable manner by suspending the powders in a liquid, such as ethanol, which does not or substantially not give rise to formation of lumps.

Also in this case, a substance influencing the sintering step, such as MgO, may be added. The suspension is dried. If desired, the dry substance may be pulverized in a ball-mill. If metal oxide powder is used, the powder is reduced, for example in the case of tungsten oxide, in hydrogen at about 700°C. From the resulting powder mixture, the conducting mass of interlocking networks of ceramic material and of metal, respectively, is obtained after sintering.

The powder mixture is joined with the granules in a predetermined ratio and mixed therewith by rolling. The mixture is compressed, for example isostatically, at a final pressure between 0.5 and 2 kbar. The moulding obtained is sintered, for example after a mechanical pretreatment, in vacuo, in a neutral or in a reducing gas up to a temperature between about 1600 and 1800°C.

In EP—A—28,885 reference is made to the US—A—4 155 758 mentioned in the opening paragraph. Although the said US Patent Specification prescribes the temperature range of 1600—1800°C to manufacture the current lead-in conductor by sintering, the said European Patent Specification states that a strong bond between ceramic material and metal is obtained in the temperature range of 1800—1975°C. Since at that temperature a strong grain growth occurs in the ceramic material, which gives rise to cavities and internal stresses, according to the said European Patent Specification metal powder is moreover incorporated in the ceramic granules. As a result, a strong grain growth is prevented. The metal powder in the granules does not contribute, however, to the electrical conductivity of the current lead-in conductor, but in fact increases the volume fraction of metal.

Experiments in connection with the invention have shown that sinter bodies having a strength of considerably less than 250 MN/m^2 (measured in a three-point bending test), are not vacuum-tight or do not remain so. The sinter bodies of the lamps according to the invention have a strength which is about 250 MN/m^2 or lies well over the said value and generally amounts to 300—400 MN/m^2. This great strength is

due to the structure of the sinter bodies in which in fact the ceramic granules of the discontinuous phase are in contact with the ceramic network of the continuous phase. During sintering, as a result numerous ceramic-ceramic bonds are obtained which anchor the continuous phase and the discontinuous phase to each other. The aforementioned comparatively low temperature of between 1600 and 1800°C for sintering the current lead-in conductor is consequently amply sufficient to obtain a great strength and a high degree of vacuum-tightness, but is on the other hand sufficiently low to prevent a strong grain growth. Therefore, it is not necessary that metal powder is incorporated in the granules of the sinter body.

Examination of rupture surfaces of the sinter bodies according to the invention containing up to 35% by volume of metal in the continuous phase have shown that these rupture surfaces extend straight through granules. Apparently not the adhesion of the continuous phase to the granules, but the inner strength of the constituents of the sinter bodies is determinative of the strength of the sinter bodies. This is in contrast with the known sinter bodies, in which ceramic granules are incorporated in a continuous phase which is composed of metal powder. Cavities at one rupture surface then correspond to granules projecting from the other rupture surface. Apparently, in these known sinter bodies there is a low adhesion of the continuous phase to the granules. In sinter bodies according to the invention having in the continuous phase a metal content increasingly exceeding 35% by volume, rupture surfaces are found to extend increasingly along granule surfaces.

An embodiment of the lamp according to the invention is shown in the drawing. In the drawing:

Fig. 1 is a perspective view of an embodiment of the lamp according to the invention;

Fig. 2 shows a detail of the lamp of Fig. 1 in longitudinal sectional view.

In Figure 1, a transparent tubular ceramic lamp vessel 1 sealed in a vacuum-tight manner is arranged in an evacuated glass outer envelope 2 which is connected to a lamp cap 3. Terminal wires 4 and 5, which are electrically connected to the lamp cap 3, carry the lamp vessel 1. The terminal wire 5 is secured as an external conductor to a sleeve 6 of niobium, which acts as one of the current lead-in conductors, while the terminal wire 4 is connected to an external current conductor 8 which is connected to a sinter body 7 as current lead-in conductor. The current lead-in conductors 6 and 7 both carry a respective electrode located in the lamp vessel 1 and are therefore not visible. The lamp vessel has an ionizable gas filling consisting of 0.4 mg of indium, 17.5 mg of mercury, 3.7 mg of thallium iodide, 30 mg of sodium iodide, 2 mg of mercury iodide and argon at a pressure at room temperature of 5330 Pa.

As shown in Figure 2, the lamp vessel 1 has at its end a ceramic disk 10, which is fixed in the lamp vessel by sintering. A sinter body 7 is connected in a vacuum-tight manner to the disk 10 by means of fusion joint material 13. When the body 7, which acts as a current lead-in conductor, is sintered, a tungsten electrode 11, 12 and an external molybdenum current conductor 8 are fixed in this body 7 and electrically connected to each other by means of the sinter body 7.

The lamp of Figures 1 and 2 can be operated vertically with the lamp cap 3 directed downwards.

Examples of sinter bodies (7) are characterized in Table 2 by their properties.

Table 2

Al_2O_3-granules size (/um) before sintering	vol. fraction W (%) in body	vol. fraction W (%) in continuous phase	vol. fraction granules (%)	resist. (mΩ.cm)	breaking strength (MN/m^2)
50 - 500	4	15	73	11	260
"	"	20	80	5.9	290
"	"	50	92	0.7	300
"	1	30	97	900	260
"	2	30	93	3.2	250
"	4	30	87	1.3	320
"	8	30	73	0.33	300
100 - 400	4	20	80	29	390
"	8	20	60	7	350
"	2	30	93	23	370
"	4	30	87	2.3	380
"	8	30	73	0.7	370
"	2	50	96	42	260
"	4	50	92	1.4	270
"	8	50	84	0.3	280
400 - 500	2	20	90	79	310
"	4	20	80	8.4	320
"	1	30	97	46	300
"	2	30	93	4.3	350
"	4	30	87	1.2	380
"	1	50	98	293	250
"	2	50	96	4.1	310
"	4	50	92	0.7	270

The sinter bodies were manufactured as follows: Al_2O_3 powder having a specific surface area of 25 m^2/g was suspended in water to which $Mg(NO_3)_2$ was added in a quantity corresponding to 250 ppm of MgO calculated with respect to Al_2O_3. The suspension was dried. The residue was broken and sieved through a sieve of 500 µm. The granulate was rolled in a ball-mill without balls and was then sieved to isolate the fraction stated in Table 1. The granules of this fraction were heated in air for 10 hours at 600°C and for 1 hour at 1200°C. These granules serve for the discontinuous phase of the sinter bodies.

Tungsten powder having a particle size of mainly 0.4 µm was suspended in ethanol and mixed with Al_2O_3 powder of the said kind (containing 259 ppm of MgO) in a volume ratio yielding the metal fraction from column 3 of Table 1. The suspension was dried; the residue was pulverized in a ball-mill. This powder serves for the continuous conducting phase from interlocking networks of the relevant sinter bodies.

The powder mixture and the granules were joined in such a ratio that the volume fraction of tungsten of column 2 of Table 1 is obtained therefrom. The powder mixture and the granules were mixed by rolling.

The mixture was pressed isostatically at a final pressure of 1.6 kbar. The moulding obtained was treated mechanically to give it the correct shape and was provided with a current conductor and an electrode. The whole was sintered for 2 hours at 1700°C.

Claims

1. A high-pressure gas discharge lamp provided with a translucent tubular ceramic lamp vessel which is sealed in a vacuum-tight manner, which accommodates a pair of electrodes and an ionizable gas filling and which is provided at its ends with current lead-in conductors each of which is connected to a respective electrode and to a respective external current conductor, at least one current lead-in conductor consisting of an electrically conducting sintered body which contains metal particles between ceramic granules, characterized in that the ceramic granules are embedded in an electrically conducting mass consisting of interweaving networks of ceramic material and metal particles respectively, and in that the volume fraction of the metal particles in the electrically conducting mass, calculated at the theoretical densities of its pure constituents, lies between 15 and 60%.

2. A high-pressure discharge lamp as claimed in Claim 1, characterized in that said volume fraction lies between 20 and 50%.

3. A high-pressure discharge lamp as claimed in Claim 2, characterized in that said volume fraction lies between 25 and 35%.

Patentansprüche

1. Hochdruckgasentladungslampe mit einem durchscheinenden röhrenförmigen keramischen Lampenkolben, der vakuumdicht abgeschlossen ist, und in dem ein Elektrodenpaar und eine ionisierbare Gasfüllung angeordnet sind, und der an seinem Ende mit Stromzuführungsleitern versehen ist, die mit je einer betreffenden Elektrode und mit einem betreffenden externen Stromleiter verbunden sind, wobei wenigstens ein Stromzuführungsleiter aus einem elektrisch leitenden gesinterten Körper besteht, der Metallpartikeln zwischen keramischen Körnern enthält, dadurch gekennzeichnet, dass die keramischen Körner in eine elektrisch leitende Masse eingebettet sind, die aus ineinander greifende Netzwerke aus keramischem Material bzw. aus Metallpartikeln besteht, und dass der Volumenteil der Metallpartikeln in der elektrisch leitenden Masse, berechnet bei den theoretischen Dichten der reinen Bestandteile, zwischen 15 und 60% liegt.

2. Hochdruckgasentladungslampe nach Anspruch 1, dadurch gekennzeichnet, dass der Volumenteil zwischen 20 und 50% liegt.

3. Hochdruckgasentladungslampe nach Anspruch 2, dadurch gekennzeichnet, dass der Volumenteil zwischen 25 und 35% liegt.

Revendications

1. Lampe à décharge dans le gaz à haute pression munie d'une ampoule céramique tubulaire translucide, qui est fermée d'une façon étanche au vide et dans laquelle sont présents une paire d'électrodes et un remplissage de gaz ionisable et qui comporte, à ses extrémités, des entrées de courant qui sont reliées chacune à une électrode respective et à une entrée de courant extérieure respective, au moins une entrée de courant étant constituée par un corps fritté électroconducteur contenant des particules métalliques entre des granules céramiques, caractérisée en ce que les granules céramiques sont noyés dans une masse électro-conductrice constituée par des réseaux entrelacés de matériau céramique et de particules métalliques respectivement et que la fraction de volume des particules métalliques dans la masse électroconductrice, rapportée aux densités théoriques de ces composants purs se situe entre 15 et 60%.

2. Lampe à décharge à haute pression selon la revendication 1, caractérisée en ce que ladite fraction de volume se situe entre 20 et 50%.

3. Lampe à décharge à haute pression selon la revendication 2, caractérisée en ce que ladite fraction de volume se situe entre 25 et 35%.

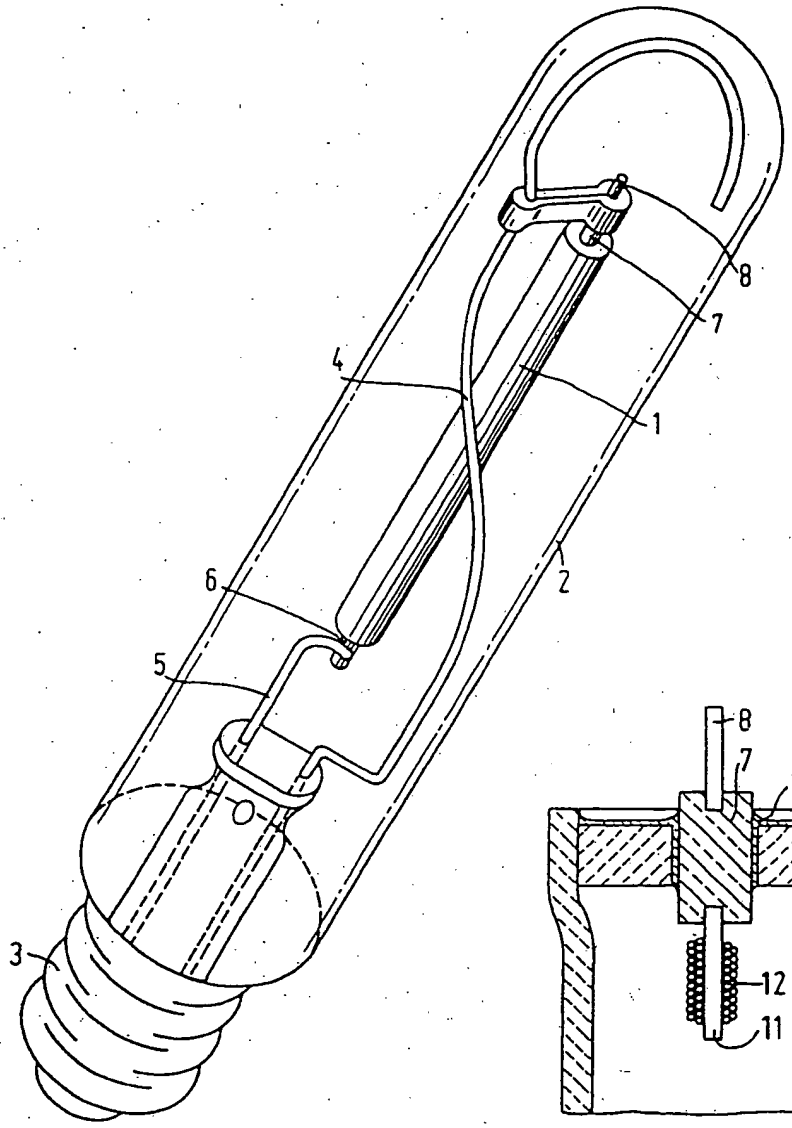

FIG.1

FIG.2